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Labib, Ashraf and Ishizaka, Alessio (2011) Selection of new production facilities with the group analytic hierarchy process ordering method. Expert Systems With Applications, 38. pp. 7317-7325. ISSN 0957-4174

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Selection of new production facilities with the Group Analytic Hierarchy Process Ordering Method

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Abstract:

This paper presents the Group Analytic Hierarchy Process Ordering (GAHPO) method: a new multi-criteria decision aid (MCDA) method for ordering alternatives in a group decision. The backbone of the method is the Analytic Hierarchy Process (AHP) which is separated into two hierarchies for a cost and a benefit analysis. From these two analyses, a partial ordinal ranking can be deduced, where three relations between alternatives exist: the preference, indifference, and incomparability. A complete cardinal ranking can also be deduced by dividing the score of the benefit analysis by the score of the cost analysis. Another particularity of GAHPO is the incorporation of 'fairness' when assigning weights to the decision makers. GAHPO has been developed to solve a real case: a selection of new production facilities with multiple stakeholders. By applying this method, we found four main advantages: significant reduction of time and effort in the decision process; easiness for the decision makers to arrive at a consensus; enhancement of the decision quality and documentation with justification of the decision made. In using the proposed method both efficiency and equity are achieved in the decision making process

Keywords: Group Analytic Hierarchy Process Ordering (GAHPO), Group decision, Cost/benefit analysis, Incomparability, Facilities selection

1. Introduction

Strategic decisions are fundamental to any company. They are usually not determined by a single decision-maker but by a group of decision-makers, who may have different objectives. In this case, two distinct methodologies are commonly used (Srdjevic, 2007): multicriteria decision-making methods or voting system. The voting system has surely high democratic properties and bypasses the data requirements of multicriteria approaches (Hurley & Lior, 2002) but moves stakeholder into a polarisation of their opinion and no intensity of their preferences can be measured. It is a head-count of yes or no. Therefore, a minority with strong convictions will unconditionally be beaten from a majority, whatever the strength of their opinion is. Furthermore, a voting system does not necessitate a modelling of the problem and therefore has difficulty to incorporate several criteria in the decision (Craven, 1992). Saaty and Shang (2007) recommend using AHP in order to resolve deficiencies of the conventional voting mechanism. AHP is a multi-criteria method developed by Saaty (1977; 1980) and applied in several area: banks (Seçme, Bayrakdaroglu, & Kahraman, 2009), manufacturing systems (Iç & Yurdakul, 2009; T.-S. Li & Huang, 2009; Yang, Chuang, & Huang, 2009), operators evaluation (Sen & Çinar, 2009), drugs selection (Vidal, Sahin,

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Martelli, Berhoun, & Bonan, 2009), site selection (Önüt, Efendigil, & Soner Kara, 2009), software evaluation (Cebeci, 2009; Chang, Wu, & Lin, 2009), evaluation of website performance (Liu & Chen, 2009), strategy selection (Chen & Wang, 2009; S. Li & Li, 2009; Limam Mansar, Reijers, & Ounnar, 2009; Wu, Lin, & Lin, 2009), supplier selection (Chamodrakas, Batis, & Martakos; H. S. Wang, Che, & Wu; T.-Y. Wang & Yang, 2009), selection of recycling technology (Y.-L. Hsu, Lee, & Kreng), firms competence evaluation (Amiri, Zandieh, Soltani, & Vahdani, 2009), weapon selection (Dagdeviren, Yavuz, & Kilinç, 2009), underground mining method selection (Naghadehi, Mikaeil, & Ataei, 2009), software design (S. H. Hsu, Kao, & Wu, 2009), organisational performance evaluation (Tseng & Lee, 2009), staff recruitment (Celik, Kandakoglu, & Er, 2009; Khosla, Goonesekera, & Chu, 2009), construction method selection (Pan, 2009), warehouse selection (Ho & Emrouznejad, 2009), technology evaluation (Lai & Tsai, 2009), route planning (Niaraki & Kim, 2009) and many others. This paper presents the Group Analytic Hierarchy Process Ordering (GAHPO), which improves the AHP on several points. We separate the cost and benefit criteria of the AHP, which simplify the appraisal and provide a more accurate result, as will be shown later. Results are then partially aggregated for an ordinal partial ranking or fully aggregated for a cardinal complete ranking. The new GAHPO method is also adapted for group decisions. The task to assign weights (importance) to the different decision-makers of the group is often a difficult one. We propose a new simple and fair method, where the weights of the members are judged by the other members of the group.

The paper starts with a literature review on the Analytic Hierarchy Process, followed by the description of the new proposed method and then finalised by an application of production facilities selection.

2. Analytic Hierarchy Process

AHP decomposes the problem into small parts in order to facilitate the decision-maker in the appraisal task. First, a hierarchy structuring the problem is constructed (figure 1). The top of the hierarchy represents the goal. Below we have the criteria, sub-criteria and alternatives. The appraisal can be constructed top-down or bottom-up (figure 2) but always using pairwise comparisons. It allows the user to concentrate only on the question “How much A is better than B?” and to ignore temporarily the other criteria and alternatives. The comparisons are entered into a matrix. If a matrix is sufficiently consistent, priorities can be calculated with the formula:

$$Aw = \lambda_{\max} w \quad (1)$$

where A comparison matrix
 λ_{\max} principal eigenvalue
w vector of the priorities

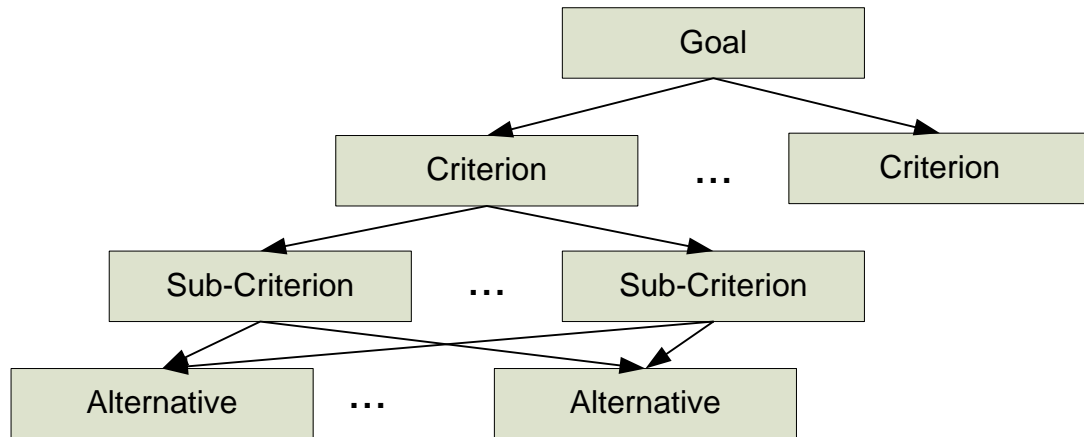


Figure 1: Hierarchy used in the AHP.

TOP DOWN + BOTTOM UP

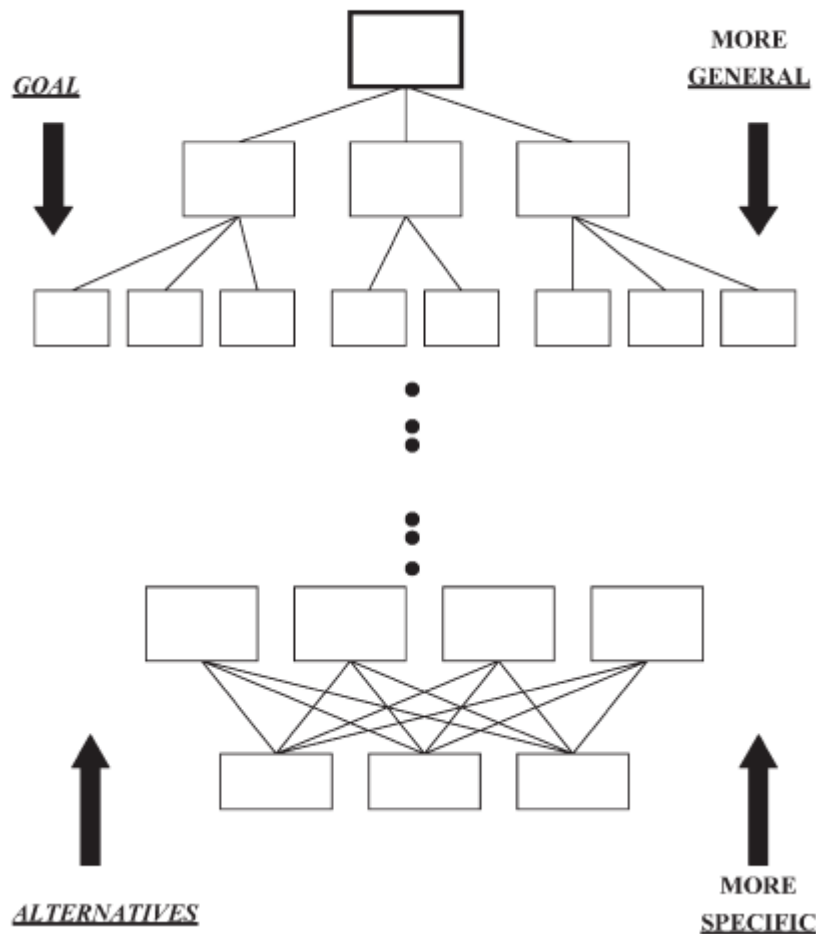


Figure 2: Top down or bottom up appraisal (Chan & Chan, 2004).

The comparison matrix contains redundant information. This redundancy serves the purpose of refining the final result as it makes the approach less dependent on one single judgement. The AHP model provides a feedback to the decision maker on the consistency of the entered judgements by a measure called consistency ratio (CR):

$$CR = \frac{CI}{RI} \quad (2)$$

$$\text{and } CI = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

where CI consistency index
 n dimension of the comparison matrix
 λ_{\max} principal eigenvalue
 RI ratio index

The ratio index (RI) is the average of the consistency index of 500 randomly generated matrices. If the consistency ratio is higher than 10%, it is recommended to revise the comparisons in order to reduce the inconsistency. Once all local priorities are available, they are aggregated with a weighted sum in order to obtain the global priorities of the alternatives.

3. Analytic Hierarchy Process Ordering

Later, it was proposed (Azis, 1990; Clayton, Wright, & Sarver; Wedley, Choo, & Schoner, 2001) to decompose the model into further subproblems, in separating criteria with opposite direction in different hierarchies: benefits versus costs. The reason of this additional decomposition is that criteria on the same direction are much easier to compare than two in opposite directions like a criterion to be minimised and another to be maximised. In this paper, we introduce the concepts of partial ordinal ranking (cost and benefit ranking are not aggregated) and complete cardinal ranking (cost and benefit ranking are aggregated).

In some problems, an order of alternatives is sufficient to take a decision. A partial ordinal ranking can be derived from the cost and benefit analysis, where:

1. *Alternative A is **better than** Alternative B* if Alternative A is ranked better than Alternative B in the cost and benefit analysis (figure 3).

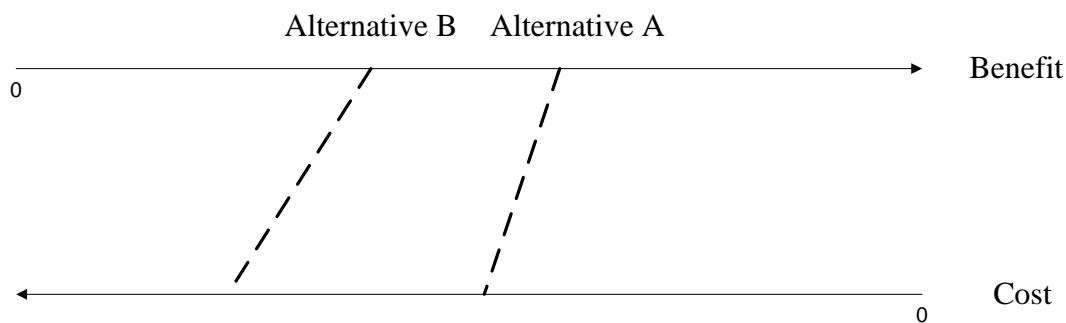


Figure 3: Graphical representation of the preference relation

2. *Alternative A is **indifferent** to Alternative B* if Alternative A has the same score than Alternative B in the cost and benefit analysis (figure 4).

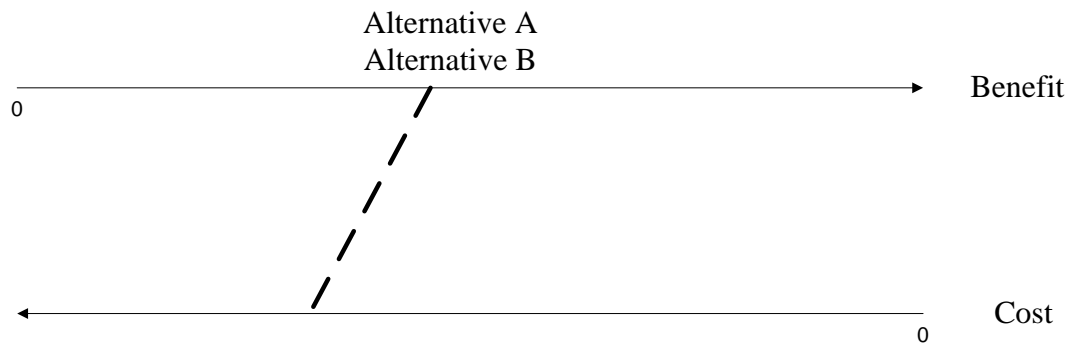


Figure 4: Graphical representation of the indifference relation

3. *Alternative A is **incomparable** to Alternative B* if Alternative A is better in one analysis and worst in the other analysis (figure 5).

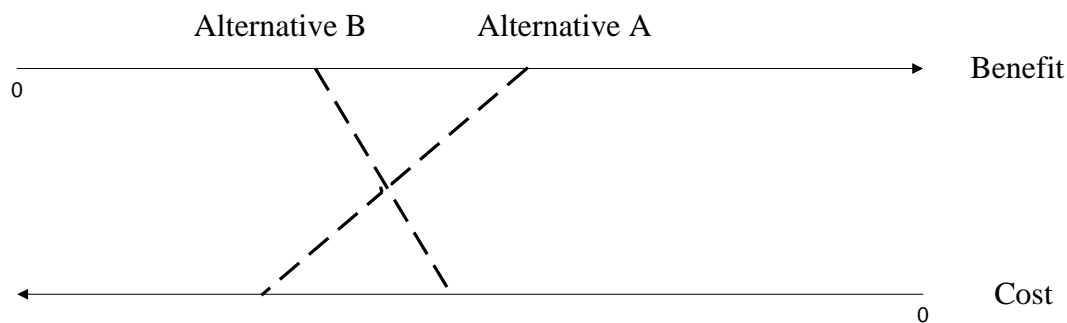


Figure 5: Graphical representation of the incomparability

Incomparability does not exist in the standard AHP. This status is important as it reveals that we cannot decide which of two alternatives is the dominant one: an alternative is better on some aspects but worst on others. In order to decide, which alternative is better, further discussion between the decision-makers moderated by the analyst is needed. This further debate may require additional information. However if a debate cannot be hold, for example because the decision-makers are unavailable, the cost and benefit analysis can be merged in one ranking. First, the importance of benefits and costs are weighted and then the weighted score of the benefit analysis is divided by the weighted score of the cost analysis. This produces the complete cardinal ranking.

4. Group decision

As a decision affects often several persons, the standard AHP has been adapted in order to be applied in group decisions. Consulting several experts avoids also bias that may be present when the judgements are considered from a single expert. There are four ways to combine the preferences into a consensus rating (table 1).

		mathematical aggregation	
		Yes	No
aggregation on:	judgements	geometric mean on judgements	consensus vote on judgements
	priorities	weighted arithmetic mean on priorities	consensus vote on priorities

Table 1: Four ways to combine preferences.

The consensus vote is used, when we have a synergistic group and not a collection of individuals. In this case, the hierarchy of the problem must be the same for all decision-makers. On the judgements level, this method requires the group to reach an agreement on the value of each entry in a matrix of pairwise comparisons. A consistent agreement is usually difficult to obtain with increasing difficulty with the number of comparison matrices and related discussions. In order to bypass this difficulty, the consensus vote can be postponed after the calculation of the priorities of each participant. O’Learly (1993) recommends this version because an early aggregation could result “in a meaningless average performance measure”. An aggregation after the calculation of priorities allows to detect decision-makers from different boards and to discuss further any disagreement.

If a consensus is difficult to achieve (e.g. with a large number of persons or distant persons), a mathematical aggregation can be adopted. Two synthesizing methods exist and provide the same results in case of perfect consistency of the pairwise matrices (T. L. Saaty & Vargas, 2005). In the first method, the geometric mean of individual evaluations are used as elements in the pairwise matrices and then priorities are computed. The geometric mean method (GMM) must be adopted instead of the arithmetical mean in order to preserve the reciprocal property (Aczél & Saaty, 1983). For example, if person A enters a comparison 9 and person

B enters 1/9, then by intuition the mathematical consensus should be $\sqrt{9 \cdot \frac{1}{9}} = 1$, which is a geometric mean and not $(9 + 1/9)/2 = 4.56$, which is an arithmetic mean. Ramanathan and Ganesh (1994) give an example where the Pareto optimality (i.e. if all group members prefer A to B, then the group decision should prefer A) is not satisfied with the GMM. Van den Honert and Lootsma (1997) argue that this violation could be expected because the pairwise assessments are a compromise of all the group members’ assessments and therefore it is a compromise that does not represent any opinion of the group member. Madu and Kuei (1995) and then Saaty and Vargas (2007) introduce a measure of the dispersion of the judgements in order to avoid this problem. If the group is not homogenous, further discussions are required to reach a consensus.

In the second method, decision-makers constitute the first level below the goal of the AHP hierarchy. Priorities are computed and then aggregated using the weighted arithmetic mean method (WAMM). Applications can be found in (Labib & Shah, 2001; Labib, Williams, & O’Connor, 1996). Arbel and Orgler (1990) have introduced a further level above the stakeholders’ level representing the several economics scenarios. This extra level determines the priorities (weights) of the stakeholders.

In a compromised method individual's derived priorities can be aggregated at each node. However according to Forman and Peniwati (1998), this method is "less meaningful and not commonly used". Aggregation methods with linear programming (Mikhailov, 2004) and Bayesian approach (Altuzarra, Moreno-Jiménez, & Salvador, 2007) have been proposed in order to take a decision even when comparisons are missing, for example when a stakeholder does not feel to have the expertise to judge a particular comparison.

Group decision may be skewed because of collusion or distortion of the judgements in order to advantage its preferred outcome. As individual identities are lost with an aggregation, we prefer to avoid an early aggregation. Condon, Golden, & Wasil (2003) have developed a programme in order to visualise the decision of each participant, which facilitate the detection of outliers.

5. Weight of stakeholders in GAHPO

If all decision-makers do not have an equal weight, their priority must be determined. The weights reflect the expertise of a decision-maker (Weiss & Rao, 1987) or the importance of the impact of the decision on the decision-maker. The weights can be allocated by a supra decision-maker or by a participatory approach. Finding a supra decision-maker or benevolent dictator, which is accepted by everybody, may be difficult. Cho and Cho (2008) have a surprising way to determine the weights with the level of inconsistency. We do not support this method because the inconsistency is a useful feed-back to the user. It indicates to the decision maker his/her consistency, recommend revision of comparisons that maybe due to a manual error in setting the comparisons, sometimes forced due to the upper limitation of the comparison scale (e.g. if the user enters first $a_{12} = 4$ and $a_{23} = 5$, he should enter $a_{13}=20$ in order to be consistent, but he can only enter $a_{13}=9$ due to the maximal value of the measurement scale). The consistency index is therefore certainly not a measure of the quality or expertise of the decision-maker. Ramanathan and Ganesh (1994) have proposed a method based on pairwise comparisons to calculate the weights. All n members fill a comparison matrix with their relative importance of each participant. A vector of priorities is calculated for each member. The n vectors of priorities are gathered in a $n \times n$ matrix and the final weight of each member is given by the eigenvector of this matrix. In order to incorporate the uncertainty of the expertise of the participants, the AHP has been combined with variable precision rough set (Xie, Zhang, Lai, & Yu, 2008) and fuzzy logic (Jaganathan, Erinjeri, & Ker, 2007).

The GAHPO also uses pairwise comparisons but only to judge other members of the group, with a veto possibility by the evaluated persons. This technique can be viewed as more fair and is applied for example in ice skating, where judges cannot evaluate competitors of the same nationality. The consistency of the weights given by the appraisers is checked with the consistency ratio formula (3).

6. Methodological approach

The case study took place in a world leading packing company, which had no previous experience in multicriteria methods. Our approach was based on four phases, each one corresponding to a meeting with the decision-makers of the company, where the researchers were facilitating the decision process.

- a) An awareness session on the GAHPO methodology was given. An understanding of the GAHPO and required inputs is necessary in order to avoid improper use of the method (Cheng, Li, & Ho, 2002). The advantages of the new decision method were clearly

explained in order that everybody accepts it and to avoid reluctance and objections during the decision process.

- b) After a brief reminder on the GAHPO, the problem and its possible solutions were clearly defined. Two hierarchies were constructed: one for costs and another for benefits.
- c) At the beginning of the third meeting, the participants were given the opportunity to revise the hierarchies. Then, each participant gave its comparisons of alternatives, criteria and participants' weights through a questionnaire. The participants' weights were given by the other group's members. Consistency was checked for each participant.
- d) Priorities are aggregated in Expert Choice. A sensitivity analysis is conducted and results are discussed.

7. A case study: selection of new production facilities

The studied packing company has two plants in England: the 'Green' plant producing paper products and the 'Plasto' plant producing plastic items. Due to a repatriation of another production plant from Scotland, the Plasto plant has to be redesigned. Three alternatives are possible:

- 1) Redesign of Plasto plant, hereafter referred to as Plant Redesign
- 2) Automation of Plasto production processes, hereafter referred to as Plant Automation
- 3) Relocation and consolidation of Green plant with Plasto, hereafter referred to as Plant Consolidation

We will now comment on the four phases of our methodological approach as described above.

7.1 An Awareness Session on the GAHPO

An half day awareness session was given to all stakeholders involved in the decision process (see next section for the list). The methodology of GAHPO without the mathematics (too complicated for the audience) and an example with Expert Choice was presented. The advantages of the GAHPO were clearly perceived. This first step is fundamental because, the way a new method is presented (and then used) can significantly impact its efficacy. The investment in time and money of using GAHPO and its supporting software was approved due to the strategic importance of the decision. It was decided to continue with the next phase.

7.2 Structure of the hierarchy model

A logically constructed hierarchy is the backbone of the entire GAHPO approach, which means the GAHPO is both a problem solving and a problem-structuring tool. The cost analysis and benefit analysis hierarchies were developed as two separate AHP models (see figures 6 and 7) in a half day brainstorming session with all stakeholders facilitated by the researchers. The cost analysis model has the goal of selecting the alternative with the lowest cost. The benefit analysis model has the goal of selecting the alternative with the highest benefit. The validity of the hierarchies was assessed by asking whether the elements of an upper level can be used as common attributes to compare the elements in the level below. The first or uppermost level identifies the stakeholders: Shareholders, Senior Managers and Middle Managers – those who have the most influence and involvement in the organisation's decision-making process. The second level is a subdivision of the decision makers in middle

management of the first level. The third level is concerned with the main criteria or objectives that affect the new production facilities selection and the last level shows the three strategic alternatives. Both cost and benefit hierarchies share the same elements in all levels except the third one. The elements of the various levels are explained in detail below:

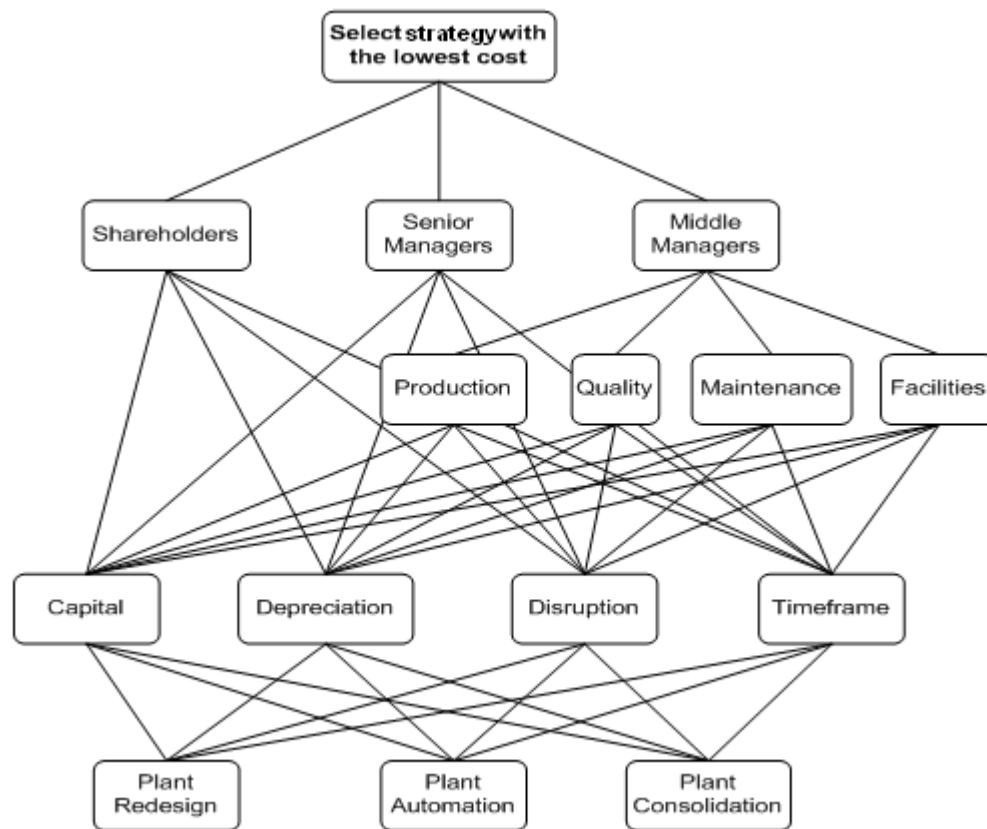


Figure 6: Cost analysis hierarchy.

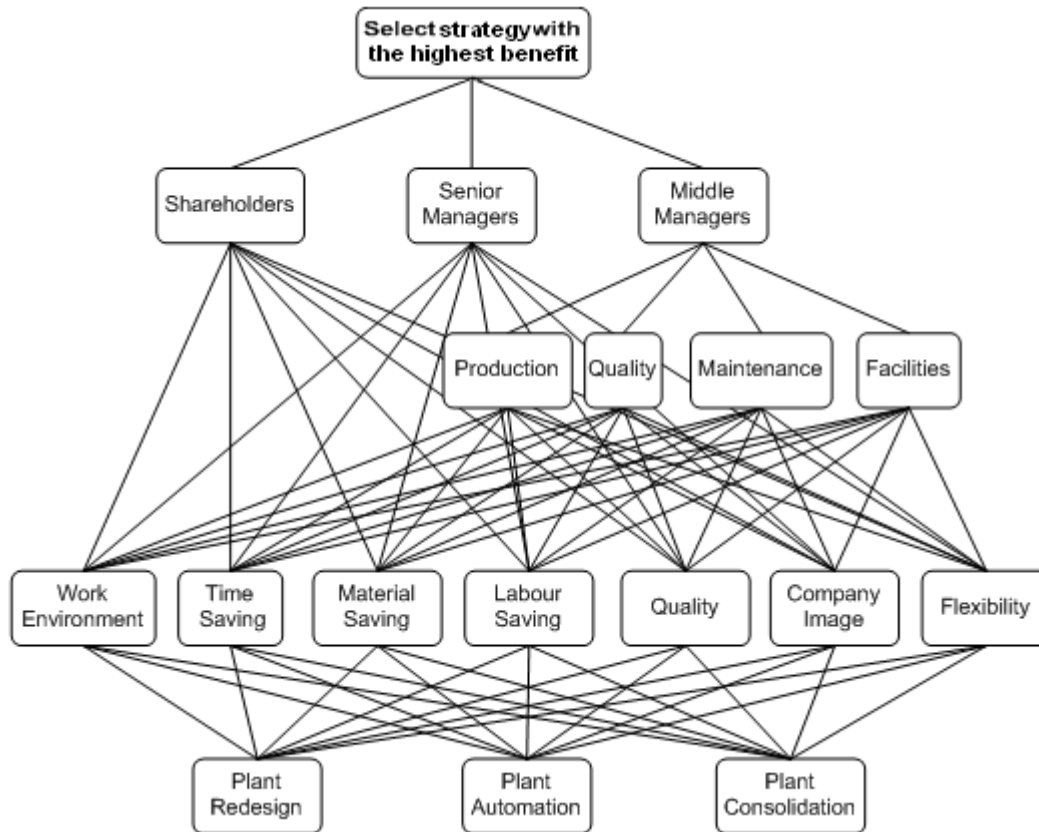


Figure 7: Benefit analysis hierarchy.

Stakeholders (Level 1 and 2)

The identification of the stakeholders (actors) was straightforward in this case. All the three alternatives called for high financial investment. This required the approval of the Shareholders. The Senior Managers make the strategic decisions for the company and obtain the funds required to implement those plans. The Middle Managers implement the strategic plans as well as help the Senior Managers in the planning process. Four Middle Managers: Production, Quality, Maintenance & Facilities are included in level two. Although they fall in the same level in the organisational hierarchy, each have dissimilar stakes, preferences and power in organisational matters. Prioritisation of their stakes was essential for a high-quality decision. This is achieved by adding a separate level in the hierarchy.

Criteria (Level 3)

This level shows the cost and benefit criteria. The logic of traditional cost-benefit analysis was used in order to identify them.

Cost criteria are those, which required direct or indirect spending from the company. Four kinds of costs were considered:

- *Capital* as all the three alternatives would require significant capital investment,
- *Depreciation* which depends on the type and duration of the investment,
- *Disruption* costs are important as any alternative would cause an amount of disruption to the existing production process,

- *Timeframe* to implement the three alternatives were also considered as a key criterion because additional costs may be incurred due to cost inflation, currency risk etc. during the project life cycle.

The benefit criteria are those, which could attain quantitative or qualitative benefits to the company. Seven criteria were identified:

- *Work environment* improvement could be beneficial to employee in their motivation and welfare at work,
- *Time saving* through reduction in packing, palletising, and shipping time,
- *Labour saving* can be gained by the reduction in the number of packers, operators and other workers,
- *Material saving* is possible by reduction in start-up losses and scrap,
- *Quality improvement* is achieved by a consistent production output and reduction in scrap,
- *Company image* can be gained with the top modern facilities,
- *Flexibility* can be achieved through the ability to expand the production facility and sharing of resources.

Alternatives (Level 4)

Three alternatives are considered:

- *Plant redesign*: it will allow accommodating new production lines.
- *Plant automation*: it will increase the capacity of production and save costs in a long term.
- *Plant consolidation*: a total new plant incorporating the current Green and Plasto plants.

7.3 Assessment of pairwise comparisons

At the beginning of the third meeting, the participants were given the opportunity to review or revise the hierarchy model, but no modification was suggested. The next step collected the pairwise comparisons through written questionnaires. This method was selected in order that participants are not influenced by others' opinions. First, the stakeholders' weight was evaluated (table 2). The judgements were given by the other members of the group. For example, the Shareholders estimate the Senior Managers five times more important than the Middle Managers in this decision. If the evaluated participants feel that they are unfairly judged, they have a veto right and further discussion is then needed. In our case, there was a high consensus ($CR=0.03$ in table 2) and the veto right was not used.

The weights can be justified based on ultimate decision making power of stakeholders as follows. The Shareholders have higher importance compared to Senior Managers and Senior Managers have higher importance than Middle Managers do. Shareholders decide which strategy to invest the money, so they have the considerable influence. The Senior Managers decide which alternatives are to be proposed for investment, so they have strong importance. The Middle Managers decide whether they have a requirement for an alternative, so they have a low – medium importance.

Stakeholder group	Top level stakeholders (actors)			Relative importance
	Shareholders	Senior Managers	Middle Managers	
Shareholders	1	3	9	0.672
Senior Managers	1/3	1	5	0.265
Middle Managers	1/9	1/5	1	0.063
Consistency Ratio (CR)				0.03

Table 2: Pairwise comparisons of main stakeholders.

The relative importance of the members of the Middle Managers was assessed in a similar way (table 3). The comparison of two Middle Managers was given by the two other Middle Managers. There was low disagreement on the comparisons and a consensus was easily found between the appraisers. The Production Manager had the most influence in the company, while the Quality, Maintenance and Facilities Managers had lesser degrees of influence in a descending order.

Sub-group of Middle Managers	Sub-group of Middle Managers				Relative importance
	Production	Quality	Maintenance	Facilities	
Production	1	3	5	5	0.538
Quality	1/3	1	5	5	0.305
Maintenance	1/5	1/5	1	1	0.078
Facilities	1/5	1/5	1/1	1	0.078
Consistency Ratio (CR)					0.06

Table 3: Pairwise comparisons of Middle Managers.

Then, each stakeholder evaluated the criteria. The process was straightforward with only few questions related to the supporting software. This suggests that our participants had no problem understanding and applying the pairwise comparisons technique. The priorities of the criteria from the stakeholders' point of view are presented in table 4 and 5.

Stakeholder group	Cost criteria			
	Capital	Depreciation	Disruption	Time-frame
Shareholders	0.447	0.053	0.105	0.396
Senior Managers	0.250	0.054	0.289	0.407
Middle Managers				
Production Manager	0.175	0.060	0.383	0.383
Quality Manager	0.113	0.064	0.411	0.411
Maintenance Manager	0.083	0.083	0.417	0.417
Facilities Manager	0.113	0.064	0.411	0.411

Table 4: Assessment of cost criteria from the stakeholder point of view.

Stakeholder group	Benefit criteria						
	Work environment	Time saving	Material saving	Labour saving	Improved quality	Company Image	Flexibility
Shareholders	0.310	0.111	0.044	0.262	0.071	0.033	0.169
Senior Managers	0.161	0.055	0.044	0.392	0.044	0.191	0.113
Middle Managers							
Production Manager	0.052	0.231	0.231	0.231	0.091	0.054	0.111
Quality Manager	0.069	0.093	0.136	0.073	0.420	0.067	0.142
Maintenance Manager	0.137	0.137	0.137	0.119	0.199	0.104	0.166
Facilities Manager	0.254	0.073	0.073	0.064	0.064	0.236	0.236

Table 5: Assessment of benefit criteria from the stakeholder point of view.

For each criterion, the relative importance (local priority) with respect to the three strategic alternatives was entered from the viewpoint of each stakeholder. To illustrate this, the priorities of the Senior Manager are shown in table 6 and table 7.

Alternatives	Cost criteria			
	Capital	Depreciation	Disruption	Time-frame
Plant Redesign	0.202	0.143	0.618	0.258
Plant Automation	0.097	0.714	0.086	0.105
Plant Consolidation	0.701	0.143	0.297	0.637

Table 6: A Senior Manager's priorities for the alternatives.

Alternatives	Benefit criteria						
	Work environment	Time saving	Material saving	Labour saving	Improved quality	Company Image	Flexibility
Plant Redesign	0.429	0.143	0.200	0.143	0.143	0.143	0.200
Plant Automation	0.429	0.714	0.600	0.714	0.714	0.714	0.200
Plant Consolidation	0.143	0.143	0.200	0.143	0.143	0.143	0.600

Table 7: A Senior Manager's priorities for the alternatives.

7.4 Calculation of priorities and sensitivity analysis

In the last step, Expert Choice was used for the calculation of the priorities and the sensitivity analysis. The participants had no difficulty in this phase because of the automation of the calculation and the user-friendliness of Expert Choice. With the sensitivity analysis, the participants were given the opportunity to check the reasonableness and robustness of the results.

a) Priorities calculation

The global priorities can be calculated in aggregating: the weighting schema for the stakeholder groups (tables 2 and 3), the importance of criteria (tables 4 and 5) and the local priorities of the alternatives with respect to the criteria (e.g. tables 6 and 7). The global priorities can be seen in table 8 and 9.

Strategic alternatives	Priorities
Plant Redesign	0.373
Plant Automation	0.142
Plant Consolidation	0.485

Table 8: Global priorities of strategic alternatives resulted from cost analysis.

Strategic alternatives	Priorities
Plant Redesign	0.277
Plant Automation	0.496
Plant Consolidation	0.227

Table 9: Global priorities of strategic alternatives resulted from benefit analysis.

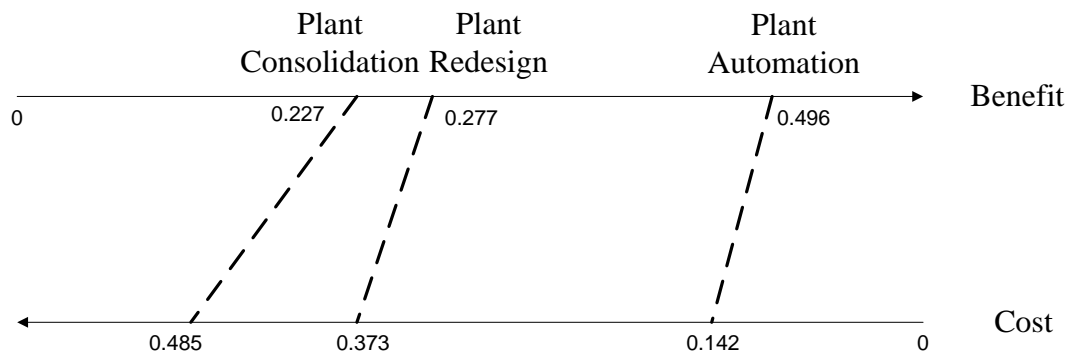


Figure 8: Graphical representation of the benefits and costs analysis.

From figure 8, it can be concluded that, the lowest cost option is ‘Plant Automation’ since it scored the least and the option with the most benefits is also ‘Plant Automation’ as it scored the highest in the benefit analysis. There is no incomparability in this problem as the cost and benefit analysis lead to the same ranking. Therefore, it is without surprise that the ‘Plant Automation’ is the most preferred alternative according to the results of the cost and benefit analysis (table 10).

Strategic alternatives	Costs	Benefits	Benefit/Cost
Plant Redesign	0.373	0.277	0.74
Plant Automation	0.142	0.496	3.49
Plant Consolidation	0.485	0.227	0.47

Table 10: Cost-Benefit Analysis.

b) Sensitivity analysis

Figures 9 and 10 show the results of the performance of the three strategic alternatives based on the stakeholders’ criteria. We can see the priority of each alternative and the weights of each Shareholder. In both figures, we can see that the ‘Plant Automation’ is the preferred alternative for each stakeholder. A ‘What-if’ analysis will therefore not change the final result, which is a robust one.

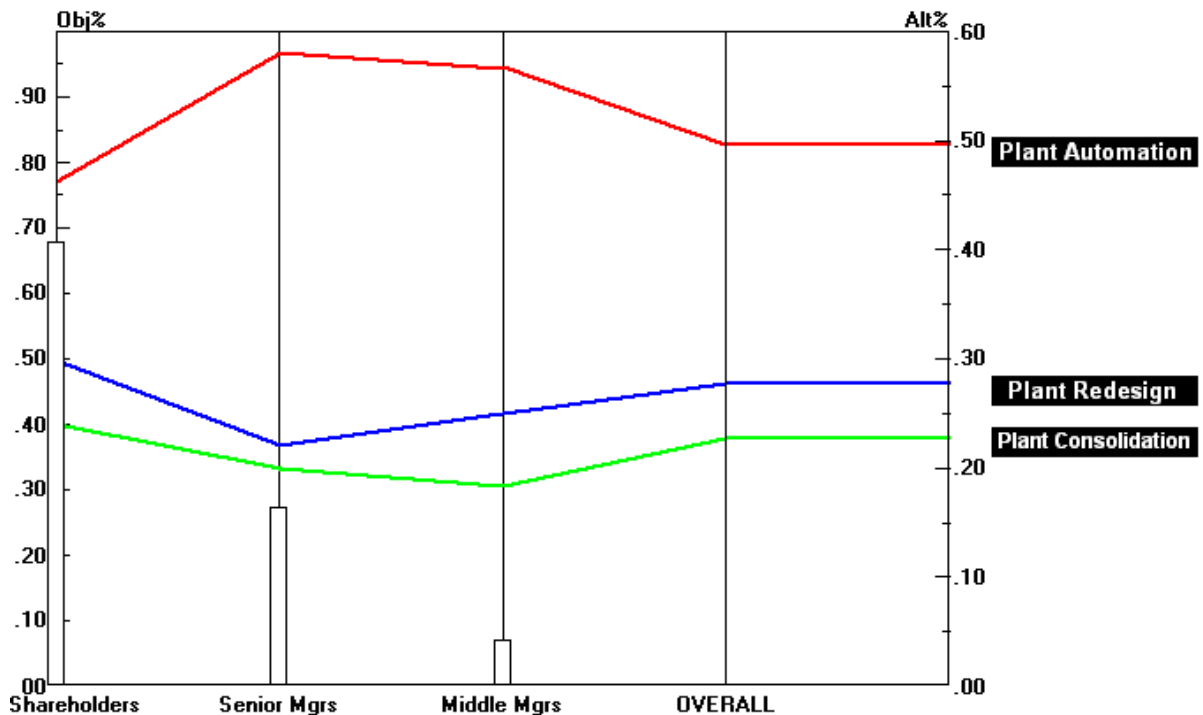


Figure 9: Performance sensitivity of the strategic alternatives from the benefits analysis. The left vertical axis represents the weight of the stakeholders and the right vertical axis gives the priority of each alternative.

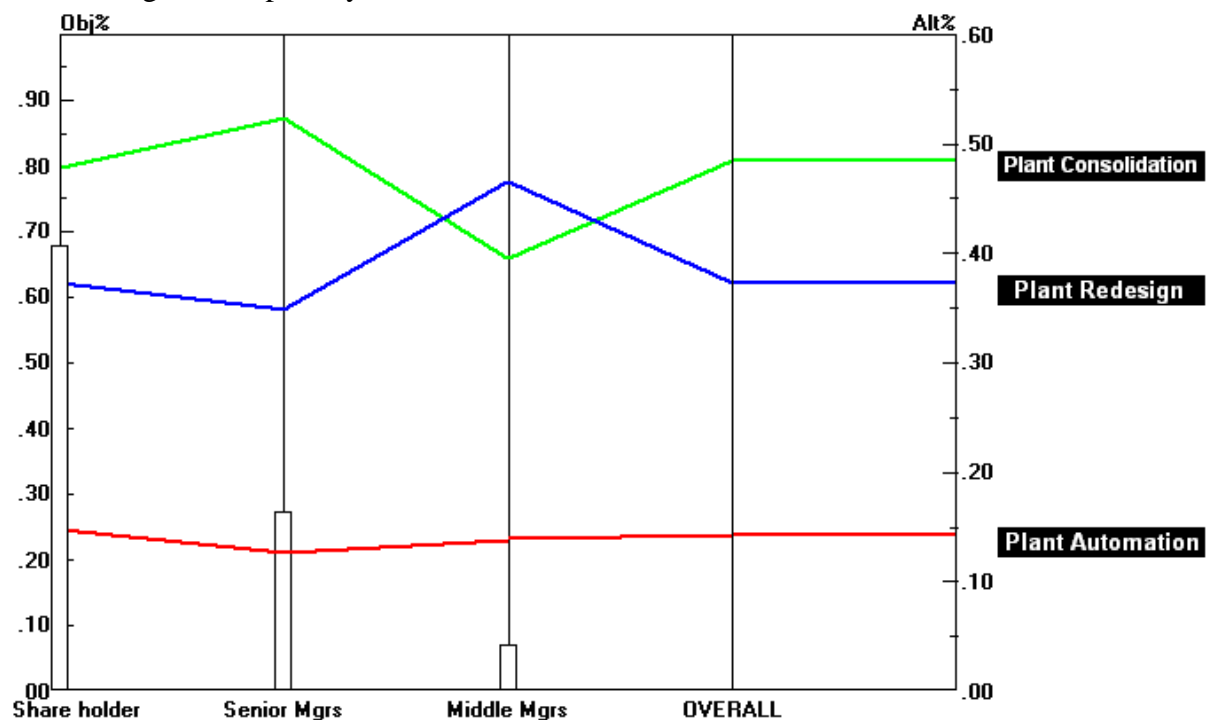


Figure 10: Performance sensitivity of the strategic alternatives from the costs analysis. The left vertical axis represents the weight of the stakeholders and the right vertical axis gives the priority of each alternative.

8. Results of the implementation

The recommendations of the model have been implemented with the general satisfaction of all stakeholders.

The successful acceptance of the proposed methodology can be attributed to the following reasons. Firstly, it helped to describe the problem and break down decision criteria into manageable components. Secondly, it led the group into making a specific decision for consensus or tradeoff. Thirdly, it provided an opportunity to examine disagreements and stimulate discussion and opinion. Fourthly, the process offered an opportunity to perform a sensitivity analysis in modifying judgments. Finally, it made possible to incorporate conflicts in perceptions and in judgments in the model.

The successful implementation of the recommendations of the model in this case study has empirically demonstrated the validity of the process and the GAHPO method.

9. Conclusions

In this paper we have presented the GAHPO a new multi-criteria decision aid method developed to solve a real problem. The backbone of the method is the AHP with several improvements:

- Cost and benefit criteria are separated in two hierarchies in order to simplify their comparisons.
- Stakeholders are incorporated in the first level of the hierarchy in order to elicit a group preference.
- The weight of each stakeholders are determined by others stakeholders. A consistency check is applied in order to verify the coherence of the comparisons given by the appraisers. A veto possibility is given to each evaluated stakeholder.
- Two rankings exist: a partial ordinal ranking and a complete cardinal ranking. A partial ordinal ranking incorporates three possible relations: the preference, indifference and incomparability relation. The complete cardinal ranking fully aggregates the cost and benefit analysis.

The result of the proposed methodology showed that out of the three strategies, plant automation was the most preferred alternative. All participants were completely satisfied from this robust result. However before the adoption, a traditional financial analysis (discounted cash flow) has been conducted in order to assess the profitability of the selected alternative. In fact, the cost-benefit analysis with the GAHPO ranks the alternatives but there is no guarantee that they will generate profits (Wedley et al., 2001). The first ranked alternative could be simply the one with the least loss.

By applying the methodology as a cost-benefit analysis, four main benefits have been achieved by the decision makers:

1. Significant reduction of time and effort in the decision process due to a structured methodology;
2. Easiness for the decision makers to arrive at a consensus, because the hierarchy model brings a common reference, which can be debated;
3. Enhancement of the decision quality, due to the consistency check and sensitivity analysis embedded in the GAHPO method;

4. Documentation and justification of the decision made.

The proposed GAHPO methodology could be easily applied to other strategic selection problems, where several stakeholders are involved.

Acknowledgements: We are grateful to Binoy Perumpalath, who helped to collect the data for the case study.

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